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目录

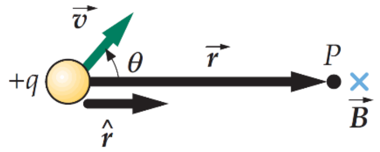
Magnetic Field 磁场

Magnetic Force 磁场力：

- Moving Charged Particle 移动电荷

$\vec{F} = q\vec{v} \times \vec{B}$ （单位 T）

$\vec{v} \times \vec{B}$ → 方向：右手定则



- Straight Line current 电流

$\vec{F} = I\vec{L} \times \vec{B}$

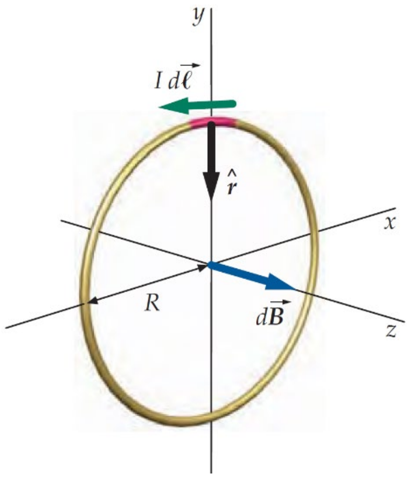
Current segment → $d\vec{F} = Id\vec{l} \times \vec{B}$

Magnetic Field 磁场

- Moving Charged Particle 移动电荷产生

$\vec{B} = \frac{\mu_0}{4\pi}\frac{q\vec{v} \times \hat{r}}{r^2} = \left(\frac{\mu_0}{4\pi}\right)\left(\frac{q}{r^2}\right)\vec{v} \times \hat{r}$ 对比记忆 → $\vec{E} = \left(\frac{1}{4\pi\varepsilon_0}\right)\left(\frac{q}{r^2}\right)\hat{r}$

$\vec{v} \times \hat{r}$ → 方向：右手定则

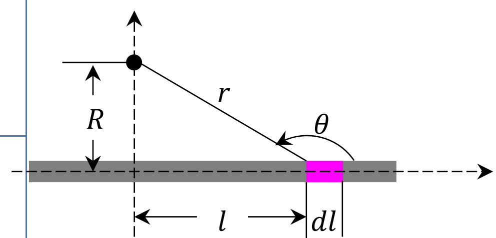


- Current 电流产生(Biot-Savart Law)

$d\vec{B} = \left(\frac{\mu_0}{4\pi}\right)\left(\frac{I}{r^2}\right)d\vec{l} \times \hat{r}$

半径 R 电流环的中心点 → $B = \left(\frac{\mu_0}{4\pi}\right)\left(\frac{I}{R^2}\right)(2\pi R) = \frac{\mu_0 I}{2R}$

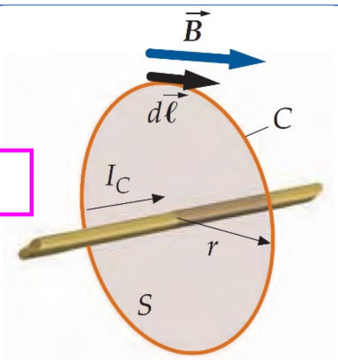
距离电流 R 的点 → $dB = \left(\frac{\mu_0}{4\pi}\right)\left(\frac{I}{R^2}\right)(-\sin\theta)d\theta$



AMPÈRE'S LAW 安培环路定律

$\oint_C \vec{B} \cdot d\vec{l} = \mu_0 I_C$

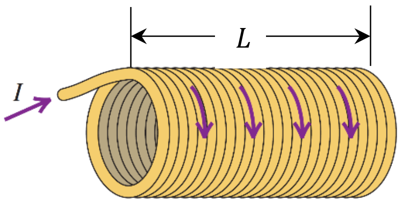
均匀对称磁场 → $B(2\pi R) = \mu_0 I_C$



The Field of a Long,Tightly Wound Solenoid

$B = \mu_0 nI$

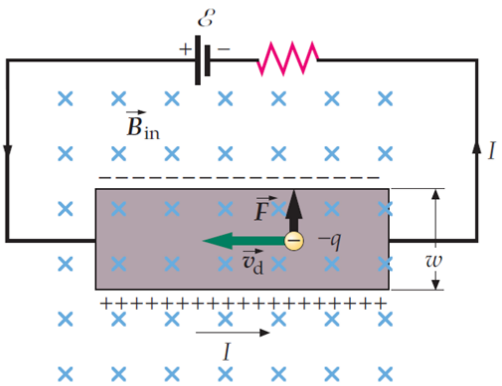
$n = \frac{N}{L}$　N → 总扎数；L → 总长度



Hall Effect 电流通过垂直方向的磁场时产生横向电荷累积的现象

- Hall Voltage

$V_H = E_H w = v_d B w = \frac{|I|}{nte}$ 需要掌握 → 霍尔电压方向；V_H与w, t, I的关系



E_H:	感生电场强度
v_d:	电荷移动速度
B:	磁感应强度
n:	电荷数量密度
w:	(电流的)宽度⇐ $A=wt$
t:	(电流的)厚度⇐ $A=wt$

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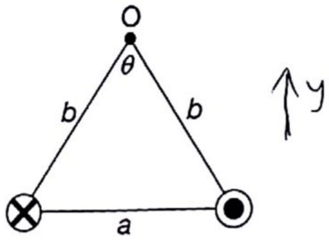
2. The diagram shows two long, straight current-carrying wires that are oriented in the plane of the page. Each wire carries current of the same magnitude I. What is the magnitude and direction of the net magnetic field at location O?



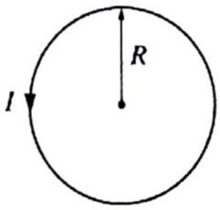
$\vec{B}_o = B_y \cdot \hat{B}_o$

$B_y = 2 \cdot \frac{\mu_0}{2\pi} \cdot \frac{I}{b} \cdot \cos\left(\frac{\pi}{2} - \theta + \frac{\theta}{2}\right)$

$B_o = \mu_0 \cdot \frac{I}{b} \cdot \cos\left(\frac{\pi}{2} - \frac{\theta}{2}\right)$

direction: down

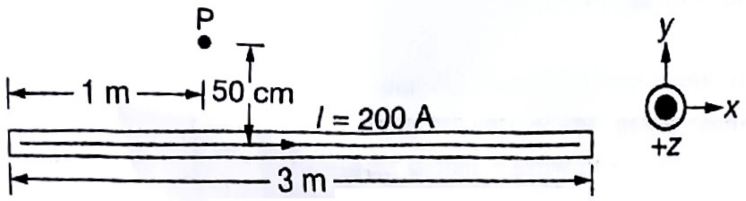
3. The single, circular wire loop of radius R shown carries a current I that produces a magnetic field B at the center of the loop. If the current remains constant while the loop is enlarged to a radius of 2R, what is the new magnetic field at the center?



$$B = \left(\frac{\mu_0}{4\pi}\right)\left(\frac{I}{R^2}\right)(2\pi R) = \frac{\mu_0 I}{2R}$$

当 R 变为 2R，中心点处 B 变为原来的

4. A 3m-long conductor carries a current of 200A toward the right. Point P is located a short distance off the wire, as shown.



a) Use the Biot-Savart law to calculate the magnetic field due to the wire at point P.

$dB = -\frac{\mu_0}{4\pi} \cdot \frac{I}{y_0} \cdot \sin\theta \, d\theta$

$B = \int_{\arctan\left(\frac{0.5m}{1m}\right)}^{\pi - \arctan\left(\frac{0.5m}{2m}\right)} dB = \int -\frac{\mu_0}{4\pi}$

$$dB = \left(\frac{\mu_0}{4\pi}\right)\left(\frac{I}{R^2}\right)(-\sin\theta)d\theta$$

$$B = \left(\frac{\mu_0}{4\pi}\right)\left(\frac{I}{R^2}\right)\int_{\arctan\frac{0.5}{1}}^{\arctan\left(\pi - \frac{0.5}{2}\right)} (-\sin\theta)d\theta$$

$$= \left(\frac{\mu_0}{4\pi}\right)\left(\frac{I}{R^2}\right)\cos\theta\Big|_{\arctan\frac{0.5}{1}}^{\arctan\left(\pi - \frac{0.5}{2}\right)}$$

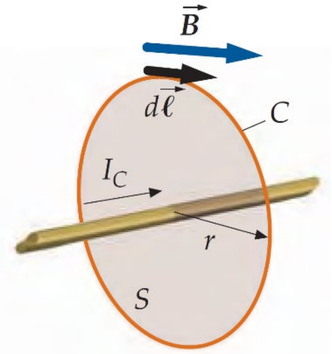
AMPÈRE'S LAW 安培环路定律

AMPÈRE'S LAW 安培环路定律

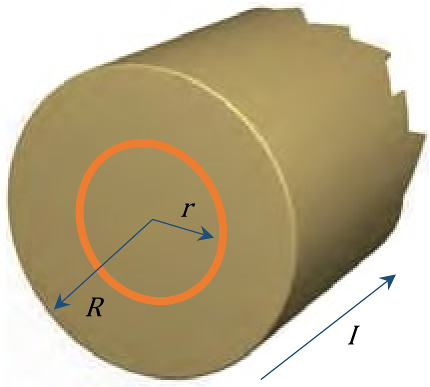
$$\oint_C \vec{B} \cdot d\vec{l} = \mu_0 I_C$$

应用场景：均匀对称磁场

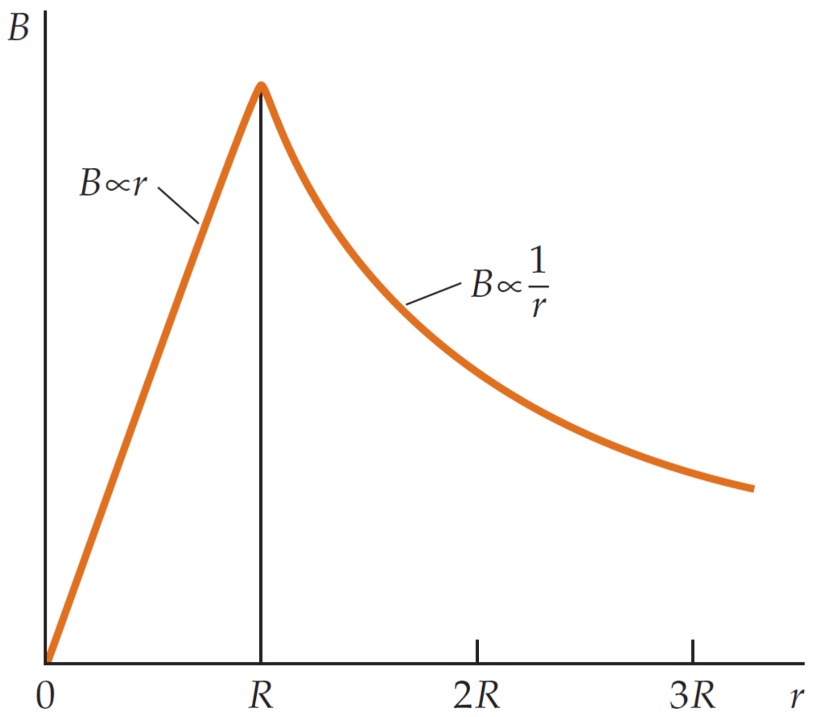
$$B(2\pi R) = \mu_0 I_C$$



Example: Along, straight wire has a radius and carries a current that is uniformly distributed over the circular cross section of the wire. Find the magnetic field both outside the wire and inside the wire.



I 均匀分布在安培环路内外	I 完全分布在安培环路之内
Step 1: 计算电流密度⇒计算电流 $J = \frac{I}{\pi R^2} \Rightarrow I(r) = J\pi r^2 = I\frac{r^2}{R^2}$	
Step 2: 安培环路定律 $B(2\pi r) = \mu_0 I$ $B(r) = \frac{\mu_0 I r}{2\pi R^2} \quad (r < R)$	Step 2: 安培环路定律 $B(2\pi r) = \mu_0 I$ $B(r) = \frac{\mu_0 I}{2\pi r} \quad (r \geq R)$



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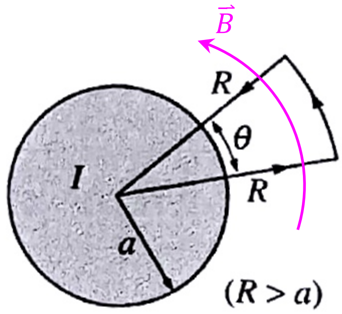
2. A long, straight wire of radius a carries a current I out of the page, which is uniformly distributed over the cross section of the wire. The value of $\oint \vec{B}\cdot d\vec{l}$, the line integral of the magnetic field $\vec{B}$ around the wedge-shaped path shown is?



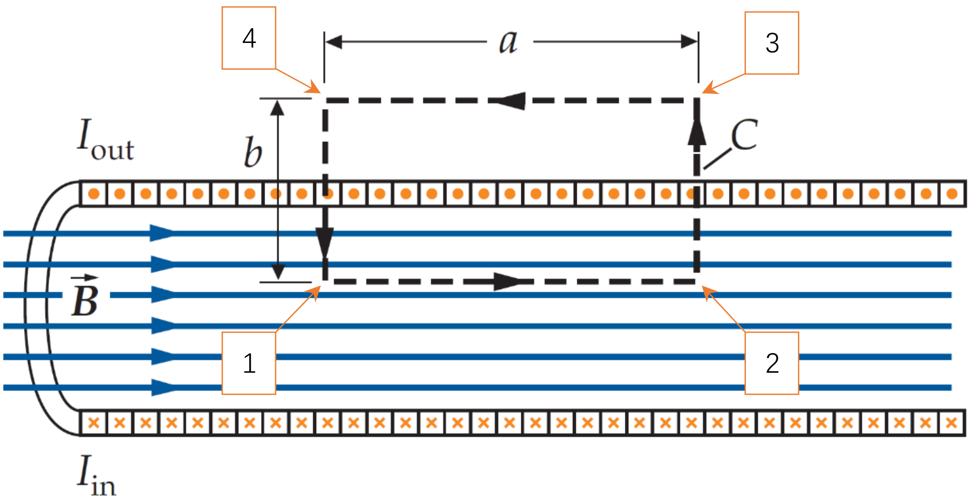
图中安培环路有三段:

1. 注意$\vec{B}$方向是垂直于半径的，所以在两个半径方向的积分$\int \vec{B}\cdot d\vec{l}=0$

2. 在平行于半径的弧上$B(\theta R)=\mu_0 I_C$，$\frac{I_C}{I}=\frac{\theta}{2\pi}$

   $\Rightarrow B(\theta R)=\mu_0\left(\frac{\theta}{2\pi}\mathrm{I}\right) \Rightarrow \ B=\frac{\mu_0 I}{2\pi R}$

Example: The figure below shows a solenoid that has n turns per unit length and carries a current I. Apply Ampère's law to the rectangular curve shown in the figure to derive an expression for the magnitude of the magnetic field. Assume that inside the solenoid the magnetic field is uniform and parallel with the central axis, and that outside the solenoid there is no magnetic field.



Solution: A rectangle shape Ampère curve is shown in the figure above which have 4 corners numbered 1,2,3,4 respectively.

Express the integral around the closed path C as the sum of the integrals along the sides of the rectangle:

$$\oint_C \vec{B}\cdot d\vec{\ell} = \int_{1\to2} \vec{B}\cdot d\vec{\ell} + \int_{2\to3} \vec{B}\cdot d\vec{\ell} + \int_{3\to4} \vec{B}\cdot d\vec{\ell} + \int_{4\to1} \vec{B}\cdot d\vec{\ell}$$

Evaluate $\int_{1\to2} \vec{B}\cdot d\vec{\ell}$:

$$\int_{1\to2} \vec{B}\cdot d\vec{\ell} = aB$$

For the paths $2\to3$ and $4\to1$, $\vec{B}$ is either zero (outside the solenoid) or is perpendicular to $d\vec{\ell}$ and so:

$$\int_{2\to3} \vec{B}\cdot d\vec{\ell} = \int_{4\to1} \vec{B}\cdot d\vec{\ell} = 0$$

For the path $3\to4$, $\vec{B}$ =0 and:

$$\int_{3\to4} \vec{B}\cdot d\vec{\ell} = 0$$

Substitute in Ampère's law to obtain:

$$\oint_C \vec{B}\cdot d\vec{\ell} = aB + 0 + 0 + 0 = aB = \mu_0 I_C = \mu_0 naI$$

Solving for B yields:

$$B = \boxed{\mu_0 nI}$$